CERTIFICATION OF TRANSLATION

I, ***Jungkum Lee***, an employee of Y.P. LEE, MOCK & PARTNERS of The Koryo Building, 1575-1 Seocho-dong, Seocho-gu, Seoul, Republic of Korea 137-875, hereby declare under penalty of perjury that I understand the Korean language and the English language; that I am fully capable of translating from Korean to English and vice versa; and that, to the best of my knowledge and belief, the statement in the English language in the attached translation of ***Korean Patent Application No. 10-2003-0004105*** consisting of ***43*** pages, have the same meanings as the statements in the Korean language in the original document, a copy of which I have examined.

Signed this 25th day of October 2006

Leejungkum

ABSTRACT

[Abstract of the Disclosure]

A droplet ejector and an ink-jet printhead using the same are provided. The droplet ejector comprises a fluid path through which a fluid moves, a nozzle being formed on one end of the fluid path, a volumetric structure, which is formed in the fluid path, is sensitive to an external stimulus, and expands to eject droplets through the nozzle, and a stimulus generator, which applies a stimulus to the volumetric structure. The volumetric structure is formed of stimulus sensitive hydrogel.

[Representative Drawing]

FIG. 6

SPECIFICATION

[Title of the Invention]

Droplet Ejector and Ink-Jet Printhead Using the Same

[Brief Description of the Drawings]

FIG. 1 is a cross-sectional view schematically illustrating a structure of a conventional thermally driven ink-jet printhead;

FIG. 2 illustrates a general structure of a piezoelectrically driven ink-jet printhead;

FIG. 3 is a cross-sectional view schematically illustrating a structure of a conventional piezoelectrically driven ink-jet printhead;

FIG. 4 is a cross-sectional view taken along line IV-IV' of FIG. 3.

FIGS. 5A and 5B are cross-sectional views schematically illustrating a structure of a conventional ink-jet printhead;

FIGS. 6 and 7 respectively show a cross-sectional view and a plane view schematically illustrating a structure of a droplet ejector according to an embodiment of the present invention

FIGS. 8A through 8D illustrate an operation of ejecting droplets using a droplet ejector according to an embodiment of the present invention;

FIGS. 9 and 10 respectively show a cross-sectional view and a plane view schematically illustrating a structure of an ink-jet printhead using a droplet ejector according to an embodiment of the present invention;

FIGS. 11 and 12 respectively show a cross-sectional view and a plane view schematically illustrating a structure of an ink-jet printhead using a droplet ejector according to another embodiment of the present invention;

FIGS. 13 and 14 respectively show a cross-sectional view and a plane view schematically illustrating a structure of an ink-jet printhead using a droplet ejector according to another embodiment of the present invention;

FIGS. 15 and 16 respectively show a cross-sectional view and a plane view schematically illustrating a structure of a droplet ejector according to another embodiment of the present invention when a stimulus is not applied to a volumetric structure;

FIGS. 17 and 18 respectively show a cross-sectional view and a plane view schematically illustrating a structure of a droplet ejector when a stimulus is applied to a volumetric structure and the volumetric structure contracts in a state shown in FIGS. 15 and 16;

FIG. 19 is a graph of temperature versus volume of temperature sensitive hydrogen;

FIGS. 20A through 20D illustrate an operation of ejecting droplets using a droplet ejector according to another embodiment of the present invention;

FIGS. 21 and 22 respectively show a cross-sectional view and a plane view schematically illustrating a structure of an ink-jet printhead using a droplet ejector according to another embodiment of the present invention;

FIG. 23 is a cross-sectional view schematically illustrating a structure of an ink-jet printhead using a droplet ejector according to another embodiment of the present invention; and

FIG. 24 is a cross-sectional view schematically illustrating a structure of an ink-jet printhead using a droplet ejector according to another embodiment of the present invention.

* Explanation of Reference numerals designating the Major Elements of the Drawings

110, 210, 510, 610 . . . nozzle

112, 512 . . . chamber

212, 612 . . . ink chamber

114, 514 . . . channel

214, 614 . . . ink channel

216, 616 . . . manifold

120, 220, 320, 420 . . . volumetric structure formed of electrical field sensitive hydrogel

520, 620, 720, 820 . . . volumetric structure formed of temperature sensitive hydrogel

130a, 230a, 330a, 430a . . . first electrode

130b, 230b, 330b, 430b . . . second electrode

150, 550 . . . droplet

530, 630, 730, 830 . . . resistance heating material

200, 600 . . . substrate

202, 602 . . . first insulating layer

204, 604 . . . second insulating layer

215, 615 . . . barrier layer

223, 623 . . . third insulating layer

224, 624 . . . metallic plate

225, 625 . . . nozzle plate

[Detailed Description of the Invention]

[Object of the Invention]

[Technical Field of the Invention and Related Art prior to the Invention]

The present invention relates to a droplet ejector and an ink-jet printhead using the same, and more particularly, to a droplet ejector which ejects ink droplets by expanding and contracting a volumetric structure sensitive to an external stimulus, and an ink-jet printhead using the same.

Typically, ink-jet printheads are devices for printing a predetermined color image by ejecting a small volume of droplet of printing ink at a desired position on a recording sheet. Ink-jet printheads are largely categorized into two types depending on ink droplet ejection mechanism: a thermally driven ink-jet printhead in which a heat source is employed to form and expand bubbles in ink causing ink droplets to be ejected, and a piezoelectrically driven ink-jet printhead in which a piezoelectric material deforms to exert pressure on ink causing ink droplets to be ejected.

Hereinafter, the ink ejection mechanism in the thermally driven ink-jet printhead will be described in greater detail. When a pulse current flows through a heater formed of a resistance heating material, heat is generated in the heater, and ink adjacent to the heater is instantaneously heated to about 300° C. As such, ink is boiled, and bubbles are generated in ink, expand, and apply pressure to an inside of an ink chamber filled with ink. As a result, ink in the vicinity of a nozzle is ejected in droplets through nozzles to the ink chamber.

Meanwhile, the thermal driving method includes a top-shooting method, a side-shooting method, and a back-shooting method according to a growth direction of bubbles and an ejection direction of ink droplets.

The top-shooting method is a method in which the growth direction of bubbles is the same as the ejection direction of ink droplets. The side-shooting method is a method in which the growth direction of bubbles is perpendicular to the ejection direction of ink droplets. The back-shooting method is a method in which the growth direction of bubbles is opposite to the ejection direction of ink droplets.

FIG. 1 is a cross-sectional view schematically illustrating a structure of a thermally driven ink-jet printhead disclosed in U.S. Patent No. 6,293,654. Referring to FIG. 1, the thermally driven ink-jet printhead includes a base plate 30 formed by a plurality of material layers stacked on a substrate, a barrier layer 40 which is formed on the base plate 30 and defines an ink chamber 52, and a nozzle plate 50 stacked on the barrier layer 40. Ink is filled in the ink chamber 42, and a heater 33 which heats ink to generate bubbles in ink is installed under the ink chamber 42. A plurality of nozzles 52 through which ink is ejected are formed in a position corresponding to each ink chamber 42.

The vertical structure of the ink-jet printhead described above will be described below in greater detail.

An insulating layer 32 formed of silicon, is formed on a substrate 31 for insulation between a heater 33 and the substrate 31. The insulating layer 32 is formed by depositing a silicon oxide layer on the substrate 31. The heater 33, which heats ink in the ink chamber 42 to generate bubbles in ink is formed on the insulating layer 32. The heater 33 is formed by depositing tantalum nitride (TaN) or thin-film tantalum-aluminum (TaAl) on the insulating layer 32 in a thin film shape. A conductor 34 for applying a current to the heater 33 is formed on the heater 33. The conductor 34 is made of a metallic material of good conductivity, such as aluminum (Al) or aluminum (Al) alloy. Specifically, the conductor 34 is formed by depositing aluminum (Al) on the heater 33 to a predetermined thickness and patterning a deposited resultant in a predetermined shape.

A passivation layer 35 for passivating the heater 33 and the conductor 34 is formed on the heater 33 and the conductor 34. The passivation layer 35 prevents the heater 33 and the conductor 34 from oxidizing or directly contacting ink, and is formed by depositing silicon nitride. In addition, an anti-cavitation layer 36 on which the ink chamber 42 is to be formed is formed on the passivation layer 35. The top surface of the anti-cavitation layer 36 forms the bottom surface of the ink chamber 42 and prevents the heater 33 from damaging due to a high pressure caused by bubble collapse in the ink chamber 42, and a tantalum thin film is used as the anti-cavitation layer 36.

Meanwhile, a barrier layer 40 for forming the ink chamber 42 is stacked on the base plate 30 formed of a plurality of material layers stacked on the substrate 31. The barrier layer 40 is formed by coating a photosensitive polymer on the base plate 30 through lamination and patterning a coated resultant. In this case, the thickness of the photosensitive polymer is determined by the height of the ink chamber 42 corresponding to the volume of ink droplets.

A nozzle plate 50 in which the nozzles 52 is formed, is stacked on the barrier layer 40. The nozzle plate 50 is formed of polyimide or nickel (Ni) and is attached to the barrier layer 40 using an adhering property of a photosensitive polymer.

However, in the thermally driven ink-jet printhead, a heater is heated at a high temperature so as to generate bubbles in ink, such that energy efficiency is low and a remaining energy should be dissipated.

FIG. 2 illustrates a general structure of a piezoelectrically driven ink-jet printhead. Referring to FIG. 2, a reservoir 2, a restrictor 3, a pressure chamber 4, and a nozzle 5, which form an ink passage, are formed in a passage formation plate 1. A piezoelectric actuator 6 is formed on the passage formation plate 1. The reservoir 2 stores ink flowing from an ink container (not shown), and the restrictor 3 is a path through which ink flows from the reservoir 2 to the pressure chamber 4. The pressure chamber 4 is filled with ink to be ejected, and the volume of the pressure chamber 4 is varied by driving the piezoelectric actuator 6, causing a variation in pressure for ejection or flow of ink.

The passage formation plate 1 is formed by cutting a plurality of thin plates formed of ceramic, metal, or synthetic resin, forming part of the ink passage, and depositing the plurality of thin plates. The piezoelectric actuator 6 is formed above the pressure chamber 4 and has a structure in which a piezoelectric thin plate and an electrode for applying a voltage to the piezoelectric thin plate are stacked. As such, a portion of the passage formation plate 1 that forms upper walls of the pressure chamber 4 serves as a vibration plate 1a deformed by the piezoelectric actuator 6.

The operation of the piezoelectrically driven ink-jet printhead having the above structure will be described below.

When the vibration plate 1a is deformed by driving the piezoelectric actuator 6, the volume of the pressure chamber 4 is reduced. Subsequently, due to a variation in pressure in the pressure chamber 4 caused by a reduction in the volume of the pressure chamber 4, ink in the pressure chamber 4 is ejected through the nozzle 5. Subsequently, when the vibration plate 1a is restored to its original shape by driving the piezoelectric actuator 6, the volume of the pressure chamber 4 is increased. Due to a variation in pressure caused by an increase in the volume of the pressure chamber 4, ink stored in the reservoir 2 flows to the pressure chamber 4 through the restrictor 3.

FIG. 3 illustrates a structure of a piezoelectrically driven ink-jet printhead disclosed in U.S. Patent No. 5,856,837. FIG. 4 is a cross-sectional view taken along line IV-IV' of FIG. 3.

Referring to FIGS. 3 and 4, the piezoelectrically driven ink-jet printhead is formed by stacking a plurality of thin plates and adhering them to one another. In other words, a first plate 11 in which a nozzle 11a through which ink is ejected is formed, is disposed in a lowermost portion of a printhead, a second plate 12, in which a reservoir 12a and an ink outlet 12b are formed, is stacked on the first plate 11, and a third plate 13, in which an ink inlet 13a and an ink outlet 13b are formed, is stacked on the second plate 12. A fourth plate 14, in which an ink inlet 14a and an ink outlet 14b are formed, is stacked on the third plate 13, and a fifth plate 15, in which a pressure chamber 15a connected to the ink inlet 14a and the ink outlet 14b is formed, is stacked on the fourth plate 14. The ink inlets 13a and 14a serve as a path through which ink flows from the reservoir 12a to the pressure chamber 15a. The ink outlets 12b, 13b, and 14b serve as a path through which ink is exhausted from the pressure chamber 15a toward the nozzle 11a. A sixth plate 16 which closes an upper portion of the pressure chamber 15a is stacked on the fifth plate 15. A driving electrode 20, which is a piezoelectric actuator, and a piezoelectric thin film 21 are formed on the sixth plate 16. Thus, the sixth plate 16 serves as a vibration plate which vibrates by the piezoelectric actuator, and the volume of the pressure chamber 15a formed under the sixth plate 16 is varied by deformation of the vibration plate.

In general, the first, second, and third plates 11, 12, and 13 are molded by etching or press-finishing a metallic thin plate, and the fourth, fifth, and sixth plates 14, 15, and 16 are molded by cutting thin-plate-shaped ceramic.

However, in the piezoelectrically driven ink-jet printhead having the above structure, in order to obtain an effective displacement of a piezoelectric thin film for ejection of ink droplets, the size of a structure becomes larger. As such, the number of nozzles per unit area is limited. In addition, in order to manufacture the piezoelectrically driven ink-jet printhead, a variety of plates are separately processed using a variety of processing methods, and then, the plates are stacked and adhered to one another. Thus, the plates should be precisely disposed and adhered.

Meanwhile, FIGS. 5A and 5B schematically illustrate a structure of an ink-jet printhead disclosed in U.S. Patent No. 6,406,131.

Referring to FIGS. 5A and 5B, a nozzle 65a is formed on an end of a channel 65 filled with ink 60, and a polymer element 70 is formed around the nozzle 65a. Here, the polymer element 70 may be in a hydrophilic or hydrophobic state according to a temperature value. Meanwhile, a heating element 75 for temperature control is formed under the polymer element 70.

In the above structure, FIG. 5A illustrates an ink-jet printhead when the polymer element 70 is in a hydrophilic state. In this case, ink 60 contacts the polymer element 70 and stays in the polymer element 70. However, if the temperature of the polymer element 70 is increased to more than a threshold temperature by the heating element 75, as shown in FIG. 5B, the polymer element 70 is changed into a hydrophobic state. Here, the threshold temperature is a phase transition temperature of a polymer. Likewise, if the polymer element 70 is changed into the hydrophobic state, ink 60 is spaced apart from the polymer element 70. In this case, a predetermined pressure is applied to an ink supply unit 90. Thus, ink 60 is not returned to the ink supply unit 90 and is ejected in droplets through a nozzle 65a onto a sheet of paper 80.

The ink-jet printhead ejects ink droplets by using a method of changing a polymer element in a hydrophobic or hydrophilic state according to a temperature value.

However, unlike the above-described method, the present invention uses a method of ejecting ink droplets by expanding and contracting a volumetric structure sensitive to an external stimulus.

[Technical Goal of the Invention]

The present invention provides a droplet ejector which ejects ink droplets by expanding and contracting a volumetric structure sensitive to an external stimulus, and an ink-jet printhead using the same.

[Structure and Operation of the Invention]

According to an aspect of the present invention, there is provided a droplet ejector, the droplet ejector comprising a fluid path through which a fluid moves, a nozzle being formed on one end of the fluid path, a volumetric structure, which is formed in the fluid path, is sensitive to an external stimulus, and expands to eject droplets through the nozzle, and a stimulus generator, which applies a stimulus to the volumetric structure.

The volumetric structure may be formed of stimulus sensitive hydrogel, and the stimulus sensitive hydrogel may be electrical field sensitive hydrogel.

The fluid path may include a chamber, which is filled with the fluid to be ejected and is formed under the nozzle, and a channel for supplying the fluid to the chamber, and the volumetric structure is formed in the chamber.

The volumetric structure may have a column shape, a hexahedral shape, or a cylindrical shape.

The stimulus generator may include a pair of electrodes respectively disposed above and below the volumetric structure. In this case, a cathode of the pair of electrodes may be disposed above the volumetric structure.

The stimulus generator may include a pair of electrodes respectively disposed at both sides of the volumetric structure.

According to another aspect of the present invention, there is provided an ink-jet printhead, the ink-jet printhead comprising a substrate on which a manifold for supplying ink is formed, a barrier layer, which is stacked on the substrate and on which an ink chamber filled with ink to be ejected and an ink channel for connecting the ink chamber and the manifold are formed, a nozzle plate, which is stacked on the barrier layer and in which a nozzle through which ink droplets are ejected is formed, a volumetric structure, which is formed in a position where ink moves, is sensitive to an external stimulus, and expands to eject ink droplets through the nozzle, and a stimulus generator, which applies a stimulus to the volumetric structure.

The volumetric structure may be formed of stimulus sensitive hydrogel, and the stimulus sensitive hydrogel may be electrical field sensitive hydrogel.

The volumetric structure may be formed in the ink chamber

Here, the volumetric structure may have a column shape, a hexahedral shape, or a cylindrical shape.

The stimulus generator may include a pair of electrodes respectively disposed above and below the volumetric structure. In this case, a cathode of the pair of electrodes may be disposed above the volumetric structure.

The stimulus generator may include a pair of electrodes respectively disposed at both sides of the volumetric structure.

According to another aspect of the present invention, there is provided a droplet ejector, the droplet ejector comprising a fluid path through which a fluid moves, a nozzle being formed on one end of the fluid path, a volumetric structure, which is formed in the fluid path, is sensitive to an external stimulus, and contracts to eject droplets through the nozzle, and a stimulus generator, which applies a stimulus to the volumetric structure.

The volumetric structure may be formed of stimulus sensitive hydrogel, and the stimulus sensitive hydrogel may be temperature sensitive hydrogel.

The stimulus generator may include a resistance heating material for applying heat to the volumetric structure.

The fluid path may include a chamber, which is filled with the fluid to be ejected and is formed under the nozzle, and a channel for supplying the fluid to the chamber.

The volumetric structure may be formed in the channel. In this case, the volumetric structure may have a column shape or a hexahedral shape.

The stimulus generator may be formed in the nozzle or in the chamber.

According to another aspect of the present invention, there is provided an ink-jet printhead, the ink-jet printhead comprising a substrate on which a manifold for supplying ink is formed, a barrier layer, which is stacked on the substrate and on which an ink chamber filled with ink to be ejected and an ink channel for connecting the ink chamber and the manifold are formed, a nozzle plate, which is stacked on the barrier layer and in which a nozzle through which ink droplets are ejected is formed, a volumetric structure, which is formed in a position where ink moves, is sensitive to an external stimulus, and contracts to eject ink droplets through the nozzle, and a stimulus generator, which applies a stimulus to the volumetric structure.

The volumetric structure may be formed of stimulus sensitive hydrogel, and the stimulus sensitive hydrogel may be temperature sensitive hydrogel.

The stimulus generator may include a resistance heating material for applying heat to the volumetric structure.

The volumetric structure may be formed in the ink channel. In this case, the volumetric structure may have a column shape or a hexahedral shape.

The volumetric structure may be formed in the nozzle or in the ink chamber.

Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings. Same reference numerals denote elements having same functions, and the size of each element may be exaggerated for clarity of explanation.

FIGS. 6 and 7 respectively show a cross-sectional view and a plane view schematically illustrating a structure of a droplet ejector according to an embodiment of the present invention.

Referring to FIGS. 6 and 7, a fluid flows to an inside of a fluid path comprising a nozzle 110, a chamber 112, and a channel 114. The nozzle 110, through which droplets are ejected, is formed on one end of the fluid path and has a taper shape such that a diameter thereof becomes smaller as the nozzle 110 extends toward an outlet. The chamber 112, filled with the fluid to be ejected, is formed under the nozzle 110, and the fluid is supplied to the chamber 112 through the channel 114.

A volumetric structure 120, formed of a material sensitive to an external stimulus, is formed in the chamber 112 filled with the fluid.

In the present embodiment, the volumetric structure 120 is formed of a material that expands when a stimulus is applied thereto and contracts to its original state when the stimulus is removed therefrom. Stimulus sensitive hydrogel is used as the material.

The stimulus sensitive hydrogel is a water containing polymer network, is a material sensitive to temperature, pH, electrical field, light, or molecular concentration, and has a large volume variation. The volume of the stimulus sensitive hydrogel may increase from several times to several hundreds of times according to its composition and the size of an external stimulus.

The stimulus sensitive hydrogel is categorized into a variety of types depending on environmental factors to which hydrogel is sensitive: temperature sensitive hydrogel, pH-sensitive hydrogel, and electrical field sensitive hydrogel. Electrical field sensitive hydrogel is used in the present embodiment.

The electrical field sensitive hydrogel has a non-isotropic characteristic that makes a volume variation in response to a stimulus be first generated toward a cathode. In addition, the electrical field sensitive hydrogel has a response time of a volume variation faster than other similar materials, and a volume variation amount and volume variation speed can be precisely controlled according to a voltage size and a pulse width.

A volumetric structure formed of stimulus sensitive hydrogel as described above may be formed through photopatterning and photopolymerization. Specifically, a liquid pre-hydrogel mixture is filled in a fluid path, and light, for example, ultraviolet rays, is irradiated on the liquid pre-hydrogel mixture through a photomask. Next, unpolymerized mixture liquid is removed such that the volumetric structure 120 having a desired shape and size is formed in the chamber 112.

For example, when the volumetric structure 120 is formed of electrical field sensitive hydrogel, the volumetric structure 120 may be formed by radiating light having a strength of about 30 mW/cm^2 on a hydrogel pre-polymer mixture composed of acrylic acid and 2-hydroxyethyl methacrylate in a 1:4 molar ratio, ethylene glycol dimethacrylate 1.0 wt%, and 2,2-dimethoxy-2-phenyl-acetophenone 3.0 wt% through the photomask and cleaning the hydrogel pre-polymer mixture with methanol.

Although the volumetric structure 120 has a column shape, the volumetric structure 120 may have a hexahedral shape or a cylindrical shape in which a through hole is formed.

A pair of first and second electrodes 130a and 130b are disposed above and below the volumetric structure 120. The first and second electrodes 130a and 130b serve as a stimulus generator which applies a stimulus to the volumetric structure 120. In the present embodiment, the first and second electrodes 130a and 130b apply an electrical field to the volumetric structure 120. As described above, since the volumetric structure 120 formed of electrical field sensitive hydrogel has a non-isotropic characteristic, preferably, the first electrode 130a is a cathode. Meanwhile, although not shown, a conductor for applying a voltage is connected to the first and second electrodes 130a and 130b.

Although the pair of first and second electrodes 130a and 130b are respectively disposed above and below the volumetric structure 120, the first and second electrodes 130a and 130b may be disposed at both sides of the volumetric structure 120.

FIGS. 8A through 8D illustrate an operation of ejecting droplets using a droplet ejector when the volumetric structure 120 is formed of electrical field sensitive hydrogel.

First, as shown in FIG. 8A, when a voltage is not applied to the two electrodes 130a and 130b, the volumetric structure 120 is maintained in a contracted state.

Subsequently, as shown in FIG. 8B, if the voltage is applied to the two electrodes 130a and 130b, an electrical field is generated between the two electrodes 130a and 130b. Due to the electrical field, the volumetric structure 120 expands. As such, a fluid in the chamber 112 is ejected through the nozzle 110.

Next, as shown in FIG. 8C, when the voltage applied to the two electrodes

130a and 130b is removed, the volumetric structure 120 contracts to its original state. Accordingly, the fluid ejected through the nozzle 110 is separated from the fluid in the nozzle 110 and is ejected in a droplet 150 by a contraction force.

Last, as shown in FIG. 8D, when the chamber 112 is refilled with fluid through the channel 114, due to a surface tension of the nozzle 110, a meniscus moves to an outlet of the nozzle 110, and the volumetric structure is restored to its initial state.

Hereinafter, an ink-jet printhead using the above-described droplet ejector will be described.

FIGS. 9 and 10 respectively show a cross-sectional view and a plane view schematically illustrating a structure of an ink-jet printhead according to an embodiment of the present invention.

Referring to FIGS. 9 and 10, the ink-jet printhead includes a substrate 200, a barrier layer 215, a nozzle plate 225, a volumetric structure 220, and a pair of first and second electrodes 230a and 230b.

Silicon wafer that is widely used to manufacture integrated circuits (ICs) may be used as the substrate 220. A manifold 216 for supplying ink is formed on the substrate 200, and the manifold 216 is connected to an ink reservoir (not shown) in which ink is stored.

A barrier layer 215 is formed on the substrate 200, and an ink chamber 212 to be filled with ink to be ejected and an ink channel 214 for connecting the ink chamber 212 and the manifold 216 are formed on the barrier layer 215. Here, the ink channel 214 is a path through which ink is supplied from the manifold 216 to the ink chamber 214.

Meanwhile, although only a unit structure of the ink-jet printhead is shown, in an ink-jet printhead manufactured in a chip state, a plurality of ink chambers are disposed in one row or two rows, but the ink chambers may be disposed in three or more rows so as to improve printing resolution.

The volumetric structure 220 that expands if a stimulus is applied thereto is formed in the ink chamber 212. In the present embodiment, the volumetric structure 220 is formed of electrical field sensitive hydrogel, which is a material that expands if an electrical field is applied to the volumetric structure 220.

Although the volumetric structure 220 has a column shape, the volumetric structure 220 may have a hexahedral shape or a cylindrical shape in which a through hole is formed.

The second electrode 230b of the pair of first and second electrodes 230a and 230b for applying an electrical field to the volumetric structure 220 is formed between the substrate 200 and the barrier layer 215. Here, the second electrode 230b is disposed below the volumetric structure 220.

Meanwhile, a first insulating layer 202 is formed between the second electrode 230b and the substrate 200. A second insulating layer 204 for passivation and insulation of the second electrode 230b is formed between the volumetric structure 220 and the second electrode 230b.

A nozzle plate 225 comprising a third insulating layer 223 and a metallic plate 224 is stacked on the barrier layer 215. A nozzle 210 is formed in a position of the nozzle plate 225, which corresponds to the center of the ink chamber 212. The nozzle 210 has a taper shape such that a diameter thereof becomes smaller as the nozzle 210 extends toward an outlet.

The first electrode 230a is formed on a bottom surface of the nozzle plate 225 to surround the nozzle 210. The first electrode 230a applies an electrical field to the volumetric structure 220 together with the second electrode 230b. In this case, preferably, the first electrode 230a is a cathode. Meanwhile, although not shown, a conductor for applying a voltage is connected to the first and second electrodes 230a and 230b.

In the above structure, when the voltage is applied to the first and second electrodes 230a and 230b, an electrical field is generated between the first and second electrodes 230a and 230b. Due to the electrical field, the volumetric structure 220 formed in the ink chamber 212 expands. As such, ink is ejected through the nozzle 210. Subsequently, when the voltage applied to the first and second electrodes 230a and 230b is removed, the expanded volumetric structure 220 contracts to its original state, and ink is ejected through the nozzle 210 in droplets by a contraction force. Next, when ink is refilled in the ink chamber 212 from the manifold 216 through the ink channel 214, due to a surface tension of the nozzle 210, a meniscus moves to an outlet of the nozzle 210, and the volumetric structure 220 is restored to its initial state.

Hereinafter, a method for manufacturing the above-described ink-jet printhead will be described.

First, the first insulating layer 202, the second electrode 230b, and the second insulating layer 204 are formed on the substrate 200.

Next, the manifold to be connected to an ink reservoir (not shown) is formed on the substrate 200.

Subsequently, the barrier layer 215 is stacked above the substrate 200, and then, the ink chamber 212 and the ink channel 214 are formed on the barrier layer 215. In this case, the ink channel 214 communicates with the manifold 216.

Next, the volumetric structure 220 is formed in the ink chamber 212. Specifically, the liquid pre-hydrogel mixture is filled in the ink chamber 212, the ink channel 214, and the manifold 216, and light, for example, ultraviolet rays, is irradiated on the liquid pre-hydrogel mixture through a photomask. Next, the unpolymerized mixture liquid is removed such that the volumetric structure 220 having a desired shape and size is formed in the chamber 212.

Last, the nozzle plate 225 comprising the third insulating layer 223 and the metallic plate 224 is stacked on the barrier layer 215, and then, the nozzle 210 and the first electrode 230a for surrounding the nozzle 210 are formed. In this case, the nozzle 210 communicates with the ink chamber 212.

As described above, the ink-jet printhead has a structure in which a pair of electrodes are disposed above and below a volumetric structure, but the electrodes may be disposed in other positions of the volumetric structure. An example thereof is shown in FIGS. 11 and 12.

Referring to FIGS. 11 and 12, a volumetric structure 320 is formed in the ink chamber 212, and a pair of first and second electrodes 330a and 330b for applying an electrical field to the volumetric structure 320 are respectively disposed below both sides of the volumetric structure 320.

Meanwhile, the volumetric structure 320 formed in the ink chamber 212 may have a variety of shapes. An example thereof is shown in FIGS. 13 and 14. Referring to FIGS. 13 and 14, a volumetric structure 420 having a cylindrical shape, in which a through hole is formed, is formed in the ink chamber 212. A pair of first and second electrodes 430a and 430b for applying an electrical field to the volumetric structure 420 are respectively disposed above and below the volumetric structure 420.

Hereinafter, a droplet ejector according to another embodiment of the present invention will be described.

FIGS. 15 through 18 illustrate a droplet ejector according to another embodiment of the present invention. FIGS. 15 and 16 respectively show a cross-sectional view and a plane view schematically illustrating a structure of a droplet ejector when a stimulus is not applied to a volumetric structure. FIGS. 17 and 18 respectively show a cross-sectional view and a plane view schematically illustrating a structure of a droplet ejector when a stimulus is applied to a volumetric structure and the volumetric structure contracts.

Referring to FIGS. 15 through 18, a fluid flows to an inside of a fluid path comprising a nozzle 510, a chamber 512, and a channel 514. The nozzle 510 through which droplets are ejected is formed on one end of the fluid path and has a taper shape such that a diameter thereof becomes smaller as the nozzle 510 extends toward an outlet. The chamber 512, filled with the fluid to be ejected, is formed under the nozzle 510, and the fluid is supplied to the chamber 512 through the channel 514.

A volumetric structure 520 which opens and closes the channel 514 due to a variation in a volume thereof is formed in the channel 514. The volumetric structure 520 is a valve which controls the flow of the fluid flowing to the channel 514 and is formed of a material sensitive to an external stimulus.

In the present embodiment, the volumetric structure 520 is formed of a material that expands when a stimulus is applied thereto and contracts to its original state when the stimulus is removed therefrom. Stimulus sensitive hydrogel is used as the material.

The stimulus sensitive hydrogel is a water containing polymer network and is categorized into a variety of types depending on environmental factors to which hydrogel is sensitive. Temperature sensitive hydrogel is used in the present embodiment.

If the temperature of the temperature sensitive hydrogel is higher than a lower critical solution temperature (LCST) of a polymer, the volume of the temperature sensitive hydrogel is reduced. If the temperature of temperature sensitive hydrogel is lower than the lower critical solution temperature (LCST) of the polymer, the volume of the temperature sensitive hydrogel is increased. Specifically, if the temperature of temperature sensitive hydrogel is lower than the LCST of the polymer, a hydrogen bond between the polymer in the temperature sensitive hydrogel and a water molecule is formed, the water molecule is absorbed in the temperature sensitive hydrogel, and the temperature sensitive hydrogel expands. If the temperature of the temperature sensitive hydrogel is higher than the LCST of the polymer, thermal agitation is increased, the hydrogen bond disappears, the water molecule is released out of the temperature sensitive hydrogel, and the temperature sensitive hydrogel contracts. The temperature sensitive hydrogel has a volume variation from several times to several hundreds of times within a temperature range of about 15-30℃. A typical volume variation is shown in FIG. 19.

A structure formed of stimulus sensitive hydrogel may be formed through photopatterning and photopolymerization. Specifically, a liquid pre-hydrogel mixture is filled in a fluid path, and light, for example, ultraviolet rays, is irradiated on the liquid pre-hydrogel mixture through a photomask. Next, unpolymerized mixture liquid is removed such that the volumetric structure 520 having a desired shape and size is formed in the channel 514.

For example, when the volumetric structure 520 is formed of temperature sensitive hydrogel, the volumetric structure 520 may be formed using a precursor solution through photopolymerization. Specifically, the volumetric structure 520 may be formed by exposing light having a strength of about 15 mW/cm^2 on a precursor solution composed of 1.09g N-isopropylacryl-amide, 62mg N.N'-methylenebisacrylamide, 77mg 2,2-dimethoxy-2-phenylaceto-phenone, 1.5mL dimethylsulphoxide, and 0.5mL deionized water through the photomask and cleaning the precursor solution with methanol.

Although the volumetric structure 520 has a column shape, the volumetric structure 520 may have a hexahedral shape. In addition, the volumetric structure 520 may be formed in the nozzle 510 or in the chamber 512 as well as the channel 514.

A resistance heating material 530 is disposed below the volumetric structure 520. The resistance heating material 530 serves as a stimulus generator which applies a stimulus to the volumetric structure 520. In the present embodiment, the resistance heating material 530 applies heat to the volumetric structure 520. Meanwhile, although not shown, a conductor for applying a voltage is connected to the resistance heating material 530.

Although the resistance heating material 530 is disposed below the volumetric structure 520, the resistance heating material 530 may be disposed in the vicinity of the volumetric structure 520, and a plurality of resistance heating materials may be disposed.

In the above structure, if the resistance heating material 530 is not heated, as shown in FIGS. 15 and 16, the volumetric structure 520 is maintained in an expanded state. As such, the channel 514 is closed. However, if the resistance heating material 530 is heated, as shown in FIGS. 17 and 18, the volumetric structure 520 contracts. As such, the channel 514 is opened.

FIGS. 20A through 20D illustrate an operation of ejecting droplets using a droplet ejector when the volumetric structure 520 is formed of temperature sensitive hydrogel.

First, as shown in FIG. 20A, if the resistance heating material 530 is not heated, the volumetric structure 520 is maintained in an expanded state. Thus, the channel 514 is closed, and the flow of a fluid does not occur.

Next, as shown in FIG. 20B, when a voltage is applied to the resistance heating material 530 and heat is generated by the resistance heating material 530, the temperature of the volumetric structure 520 increases. As such, the volumetric structure 520 contracts, and the channel 514 is opened. In this case, due to a pressure applied from a fluid reservoir (not shown) connected to the channel 514, the flow of the fluid occurs, and the fluid in the chamber 512 is ejected through the nozzle 510.

Subsequently, as shown in FIG. 20C, when the voltage applied to the resistance heating material 530 is removed, the volumetric structure 520 is cooled and expands to its original state. As such, the channel 514 is closed again. In this case, the fluid ejected through the nozzle 510 is separated from the fluid in the nozzle 510 and is ejected in a droplet 550.

Last, as shown in FIG. 20D, the channel 514 is completely closed, the droplet 550 is separated from the nozzle 510, the movement of a meniscus is stabilized, and the volumetric structure 520 is restored to its initial state.

Hereinafter, an ink-jet printhead using the above-described droplet ejector will be described.

FIGS. 21 and 22 respectively show a cross-sectional view and a plane view schematically illustrating a structure of an ink-jet printhead according to an embodiment of the present invention.

Referring to FIGS. 21 and 22, the ink-jet printhead includes a substrate 600, a barrier layer 615, a nozzle plate 625, a volumetric structure 620, and a resistance heating material 630.

Silicon wafer that is widely used to manufacture integrated circuits (ICs) may be used as the substrate 600. A manifold 616 for supplying ink is formed on the substrate 600. The manifold 616 is connected to an ink reservoir (not shown) in which ink is stored.

A barrier layer 615 is formed on the substrate 600, and an ink chamber 612 to be filled with ink to be ejected and an ink channel 614 for connecting the ink chamber 612 and the manifold 616 are formed on the barrier layer 615. Here, the ink channel 614 is a path through which ink is supplied from the manifold 616 to the ink chamber 614.

Meanwhile, although only a unit structure of the ink-jet printhead is shown, in an ink-jet printhead manufactured in a chip state, a plurality of ink chambers are disposed in one row or two rows, but the ink chambers may be disposed in three or more rows so as to improve printing resolution.

The volumetric structure 620 that contracts when a stimulus is applied thereto is formed in the ink channel 614. In the present embodiment, the volumetric structure 620 is formed of temperature sensitive hydrogel, which is a material that contracts if heat is applied to the volumetric structure 620.

Although the volumetric structure 620 has a columnar shape, the volumetric structure 620 may have a hexahedral shape.

The resistance heating material 630 for applying heat to the volumetric structure 620 is formed between the substrate 600 and the barrier layer 615. Here, the resistance heating material 630 is disposed below the volumetric structure 620. The resistance heating material 630 may be disposed in the vicinity of the volumetric structure 620, and a plurality of resistance heating materials may be disposed. Although not shown, a conductor for applying a voltage is connected to the resistance heating material 630.

Meanwhile, a first insulating layer 602 is formed between the resistance heating material 630 and the substrate 600. A second insulating layer 604 for passivation and insulation of the resistance heating material 630 is formed between the resistance heating material 630 and the volumetric structure 620.

A nozzle plate 625 comprising a third insulating layer 623 and a metallic plate 624 is stacked on the barrier layer 615. A nozzle 610 is formed in a position of the nozzle plate 625, which corresponds to the center of the ink chamber 612. The nozzle 610 has a taper shape such that a diameter thereof becomes smaller as the nozzle 610 extends toward an outlet.

In the above structure, if a voltage is applied to the resistance heating material 630 and heat is generated in the resistance heating material 630, the temperature of the volumetric structure 620 increases, and the volumetric structure 620 contracts. As such, ink flows from the ink reservoir (not shown) through the ink channel 614, and ink is ejected in droplets through the nozzle 610. Subsequently, if the voltage applied to the resistance heating material 630 is removed, the temperature of the volumetric structure 620 reduces, and the volumetric structure 620 expands in its original state and is restored to its initial state.

Hereinafter, a method for manufacturing the above-described ink-jet printhead will be described.

First, the first insulating layer 602, the resistance heating material 630, and the second insulating layer 604 are formed on the substrate 600.

Next, the manifold 616 to be connected to an ink reservoir (not shown) is formed on the substrate 600.

Subsequently, the barrier layer 615 is stacked above the substrate 600, and then, the ink chamber 612 and the ink channel 614 are formed on the barrier layer 615. In this case, the ink channel 614 communicates with the manifold 616.

Next, the volumetric structure 620 is formed in the ink channel 614. Specifically, the liquid pre-hydrogel mixture is filled in the ink chamber 612, the ink channel 614, and the manifold 616, and light, for example, ultraviolet rays, is irradiated on the liquid pre-hydrogel mixture through the photomask. Next, the unpolymerized mixture liquid is removed such that the volumetric structure 620 having a desired shape and size is formed in the ink chamber 614.

Last, the nozzle plate 625 comprising the third insulating layer 623 and the metallic plate 624 is stacked on the barrier layer 615, and then, the nozzle 610 is formed. In this case, the nozzle 610 communicates with the ink chamber 612.

As above, the ink-jet printhead has a structure in which a volumetric structure is formed in an ink channel. As shown in FIGS. 23 and 24, the volumetric structure may be formed in the nozzle or the ink chamber.

First, referring to FIG. 23, a volumetric structure 720 is formed along an inner wall of the nozzle 610, and a resistance heating material 730 is disposed to surround the volumetric structure 720. In a state where a voltage is not applied to the resistance heating material 730, the volumetric structure 720 expands and closes the nozzle 610. However, when heat is generated in the resistance heating material 730, the volumetric structure 720 contracts in a direction of arrow. As such, ink droplets are ejected through a through hole formed in the center of the volumetric structure 720.

Next, referring to FIG. 24, a volumetric structure 820 is formed in the ink chamber 612, and a resistance heating material 830 is disposed below the volumetric structure 820. When a voltage is not applied to the resistance heating material 830, the volumetric structure 820 expands and closes the nozzle 610. However, when heat is generated in the resistance heating material 830, the volumetric structure 820 contracts in a direction of arrow. As such, the nozzle 610 is opened, and ink droplets are ejected through the nozzle 610.

While this invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

[Effect of the Invention]

As described above, the droplet ejector and the ink-jet printhead using the same according to the present invention have the following effects. First, the droplet ejector and the ink-jet printhead can be driven within a low temperature range of about 15-30°C, such that lowering of energy efficiency and dissipating of a remaining thermal energy do not occur in a thermally driven ink-jet printhead. Second, the droplet ejector and the ink-jet printhead have a simple structure, and the size thereof becomes smaller, such that a nozzle becomes highly integrated. Third, the composition of a material of a volumetric structure or stimulus conditions are adjusted, thereby varying a volume variation amount such that the size of ejected droplets is actively controlled. Fourth, the position, size, and volume expansion ratio of the volumetric structure are properly adjusted, such that backflow during droplet ejection is reduced and a driving force is effectively utilized toward a nozzle. Fifth, if stimulus sensitive hydrogel is used as the material of the volumetric structure, a temperature, an electrical field and light are selected using an external stimulus to cause a volume variation, such that a variety of driving methods are used. Sixth, the volumetric structure is formed in a chamber by a general semiconductor device process, such that a manufacturing process is simplified.

What is claimed is:

1. A droplet ejector comprising:

a fluid path through which a fluid moves, a nozzle being formed on one end of the fluid path;

a volumetric structure, which is formed in the fluid path, is sensitive to an external stimulus, and expands to eject droplets through the nozzle; and

a stimulus generator, which applies a stimulus to the volumetric structure.

2. The droplet ejector of claim 1, wherein the volumetric structure is formed of stimulus sensitive hydrogel.

3. The droplet ejector of claim 2, wherein the stimulus sensitive hydrogel is electrical field sensitive hydrogel.

4. The droplet ejector of claim 3, wherein the fluid path includes a chamber, which is filled with the fluid to be ejected and is formed under the nozzle, and a channel for supplying the fluid to the chamber, and the volumetric structure is formed in the chamber.

5. The droplet ejector of claim 4, wherein the volumetric structure has a column shape, a hexahedral shape, or a cylindrical shape.

6. The droplet ejector of claim 4, wherein the stimulus generator includes a pair of electrodes respectively disposed above and below the volumetric structure.

7. The droplet ejector of claim 6, wherein a cathode of the pair of electrodes is disposed above the volumetric structure.

8. The droplet ejector of claim 4, wherein the stimulus generator includes a pair of electrodes respectively disposed at both sides of the volumetric structure.

9. An ink-jet printhead comprising:

a substrate on which a manifold for supplying ink is formed;

a barrier layer, which is stacked on the substrate and on which an ink chamber filled with ink to be ejected and an ink channel for connecting the ink chamber and the manifold are formed;

a nozzle plate, which is stacked on the barrier layer and in which a nozzle through which ink droplets are ejected is formed;

a volumetric structure, which is formed in a position where ink moves, is sensitive to an external stimulus, and expands to eject ink droplets through the nozzle; and

a stimulus generator, which applies a stimulus to the volumetric structure.

10. The ink-jet printhead of claim 9, wherein the volumetric structure is formed of stimulus sensitive hydrogel.

11. The ink-jet printhead of claim 10, wherein the stimulus sensitive hydrogel is electrical field sensitive hydrogel.

12. The ink-jet printhead of claim 11, wherein the volumetric structure is formed in the ink chamber.

13. The ink-jet printhead of claim 12, wherein the volumetric structure has a column shape, a hexahedral shape, or a cylindrical shape.

14. The ink-jet printhead of claim 12, wherein the stimulus generator includes a pair of electrodes respectively disposed above and below the volumetric structure.

15. The ink-jet printhead of claim 14, wherein a cathode of the pair of electrodes is disposed above the volumetric structure.

16. The ink-jet printhead of claim 12, wherein the stimulus generator includes a pair of electrodes respectively disposed at both sides of the volumetric structure.

17. A droplet ejector comprising:

a fluid path through which a fluid moves, a nozzle being formed on one end of the fluid path;

a volumetric structure, which is formed in the fluid path, is sensitive to an external stimulus, and contracts to eject droplets through the nozzle; and

a stimulus generator, which applies a stimulus to the volumetric structure.

18. The droplet ejector of claim 17, wherein the volumetric structure is formed of stimulus sensitive hydrogel.

19. The droplet ejector of claim 18, wherein the stimulus sensitive hydrogel is temperature sensitive hydrogel.

20. The droplet ejector of claim 19, wherein the stimulus generator includes a resistance heating material for applying heat to the volumetric structure.

21. The droplet ejector of claim 20, wherein the fluid path includes a chamber, which is filled with the fluid to be ejected and is formed under the nozzle, and a channel for supplying the fluid to the chamber.

22. The droplet ejector of claim 21, wherein the volumetric structure is formed in the channel.

23. The droplet ejector of claim 22, wherein the volumetric structure has a column shape or a hexahedral shape.

24. The droplet ejector of claim 21, wherein the stimulus generator is formed in the nozzle.

25. The droplet ejector of claim 21, wherein the stimulus generator is formed in the chamber.

26. An ink-jet printhead comprising:

a substrate on which a manifold for supplying ink is formed;

a barrier layer, which is stacked on the substrate and on which an ink chamber filled with ink to be ejected and an ink channel for connecting the ink chamber and the manifold are formed;

a nozzle plate, which is stacked on the barrier layer and in which a nozzle through which ink droplets are ejected is formed;

a volumetric structure, which is formed in a position where ink moves, is sensitive to an external stimulus, and contracts to eject ink droplets through the nozzle; and

a stimulus generator, which applies a stimulus to the volumetric structure.

27. The ink-jet printhead of claim 26, wherein the volumetric structure is formed of stimulus sensitive hydrogel.

28. The ink-jet printhead of claim 27, wherein the stimulus sensitive hydrogel is temperature sensitive hydrogel.

29. The ink-jet printhead of claim 28, wherein the stimulus generator includes a resistance heating material for applying heat to the volumetric structure.

30. The ink-jet printhead of claim 29, wherein the volumetric structure is formed in the ink channel.

31. The ink-jet printhead of claim 30, wherein the volumetric structure has a column shape or a hexahedral shape.

32. The ink-jet printhead of claim 29, wherein the volumetric structure is formed in the nozzle.

33. The ink-jet printhead of claim 29, wherein the volumetric structure is formed in the ink chamber.

DRAWINGS

FIG. 1

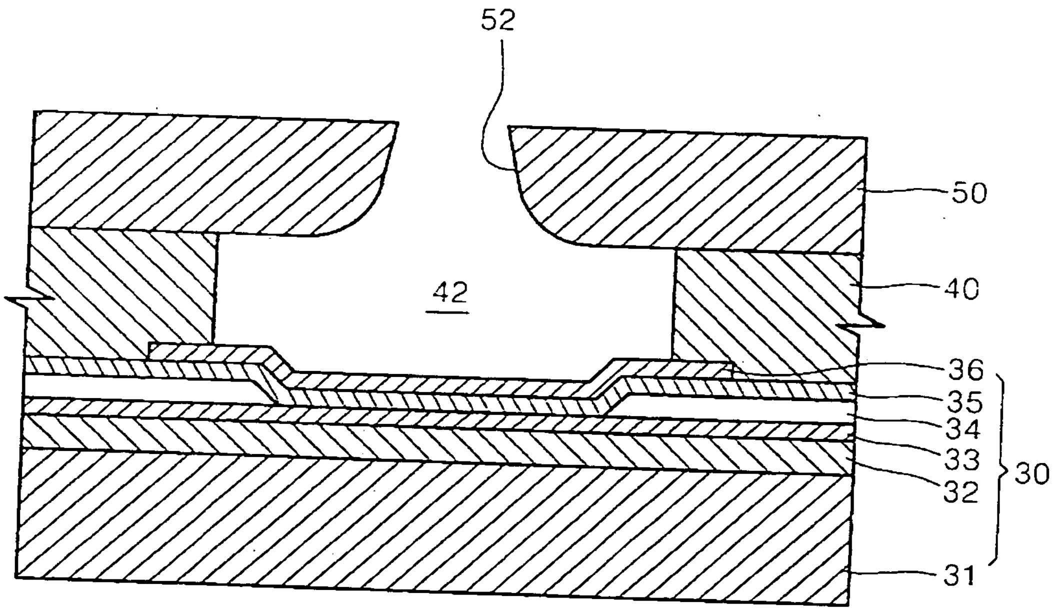


FIG. 2

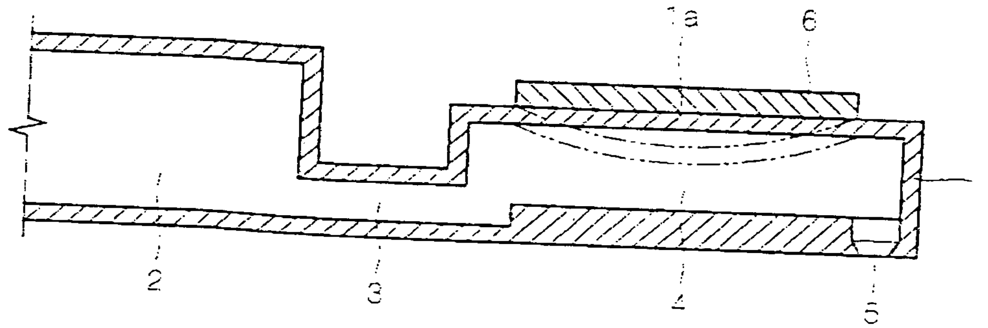

1a
6
1
2
3
4
5

FIG. 3

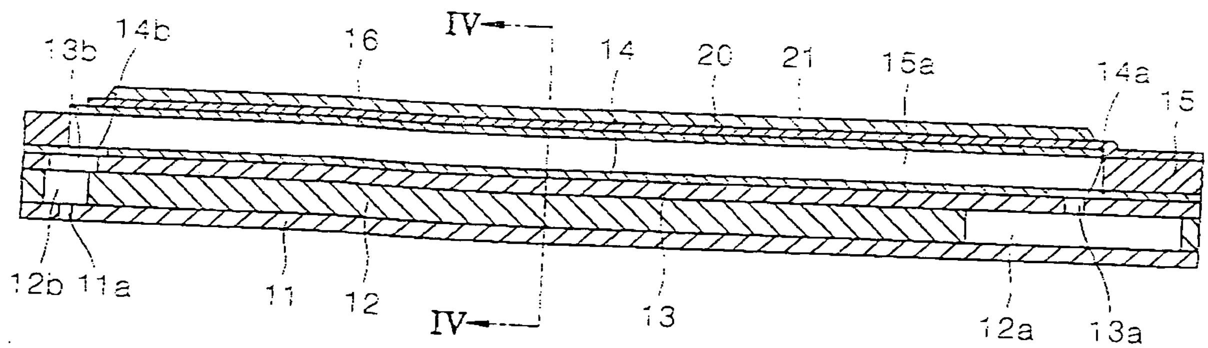

13b
14b
16
IV
14
20
21
15a
14a
15
12b
11a
11
12
IV
13
12a
13a

FIG. 4

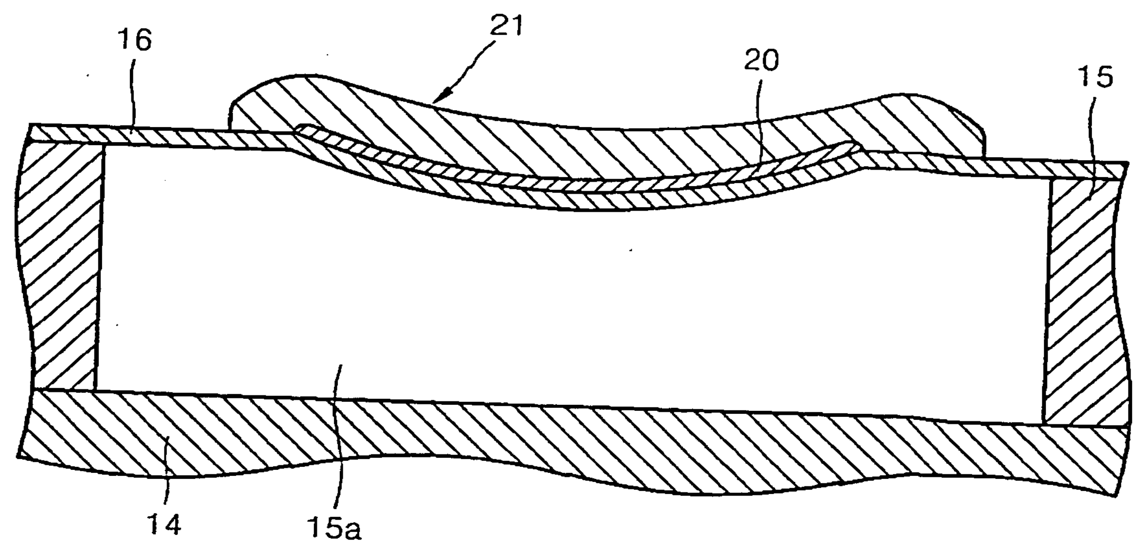


FIG. 5A

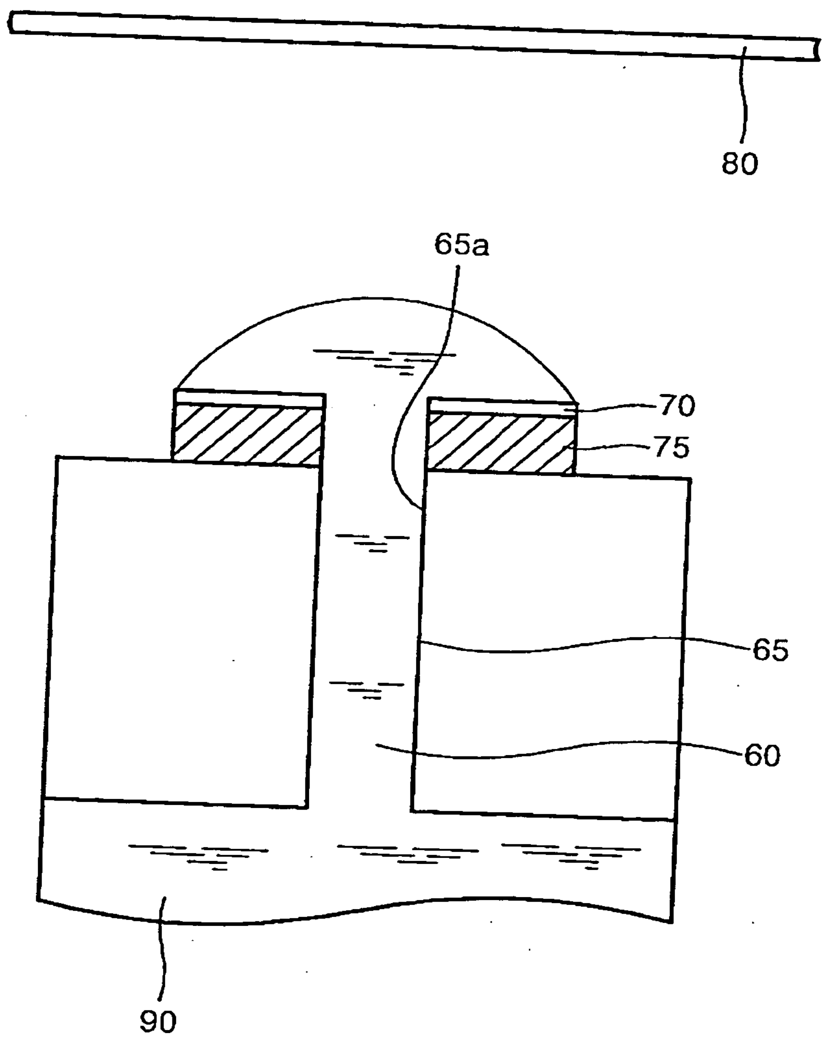


FIG. 5B

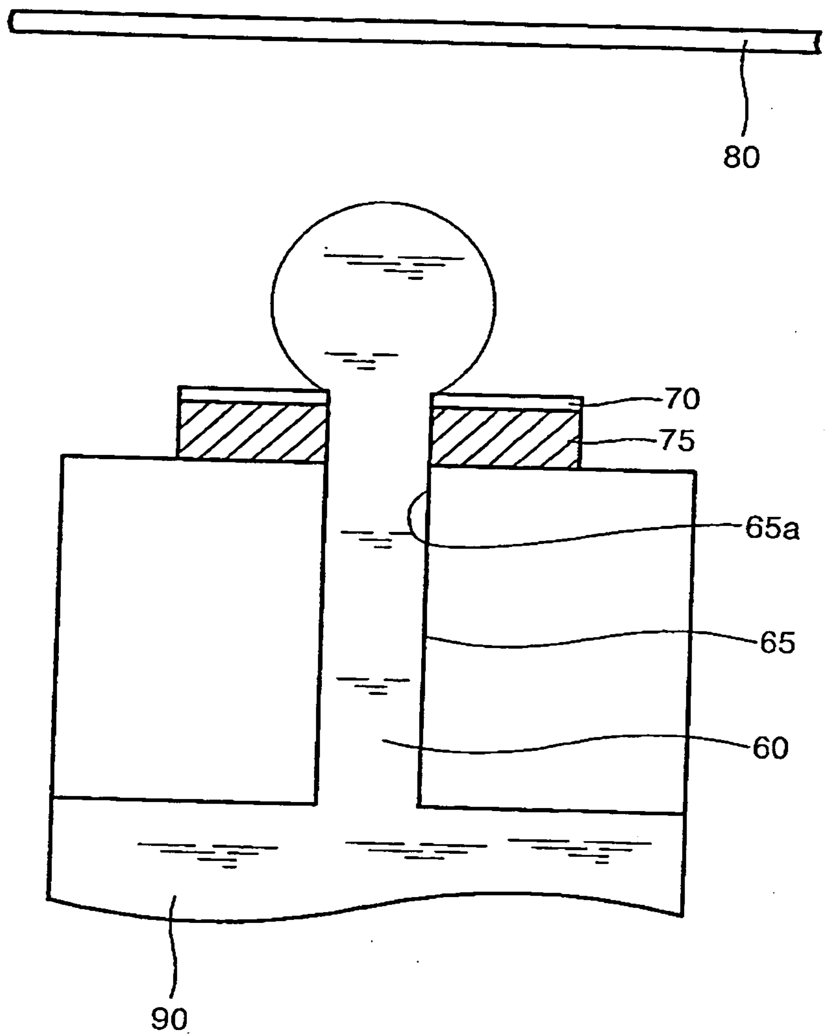


FIG. 6

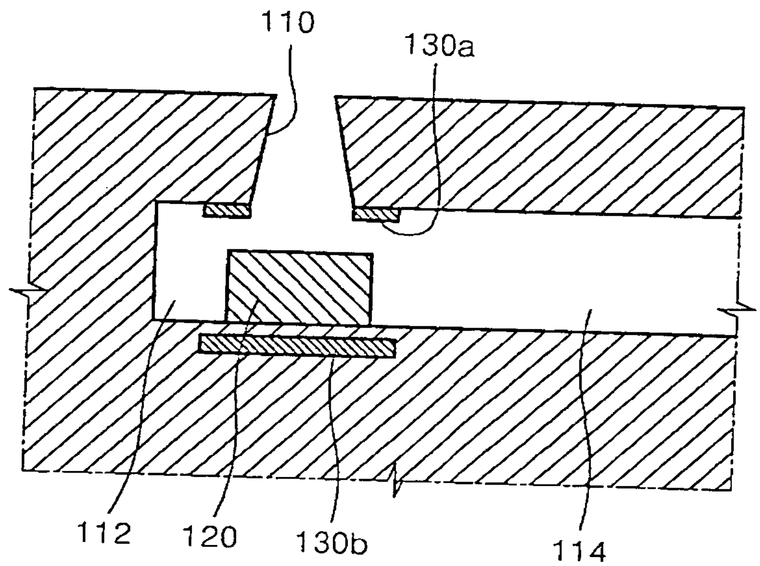


FIG. 7

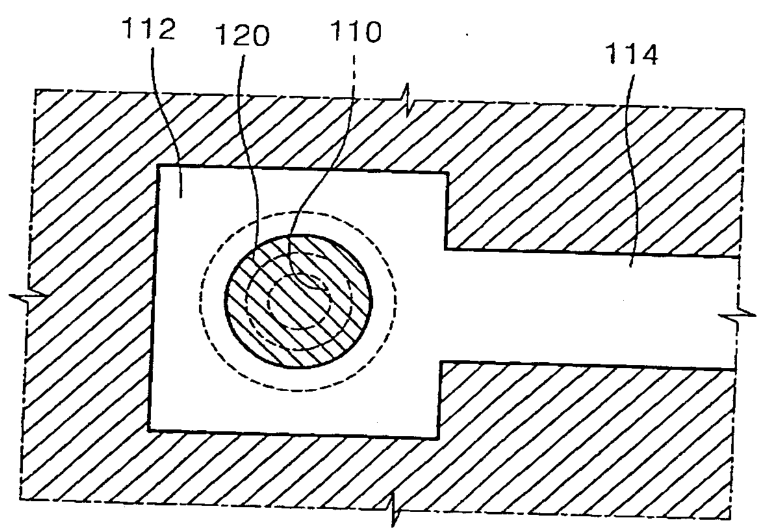


FIG. 8A

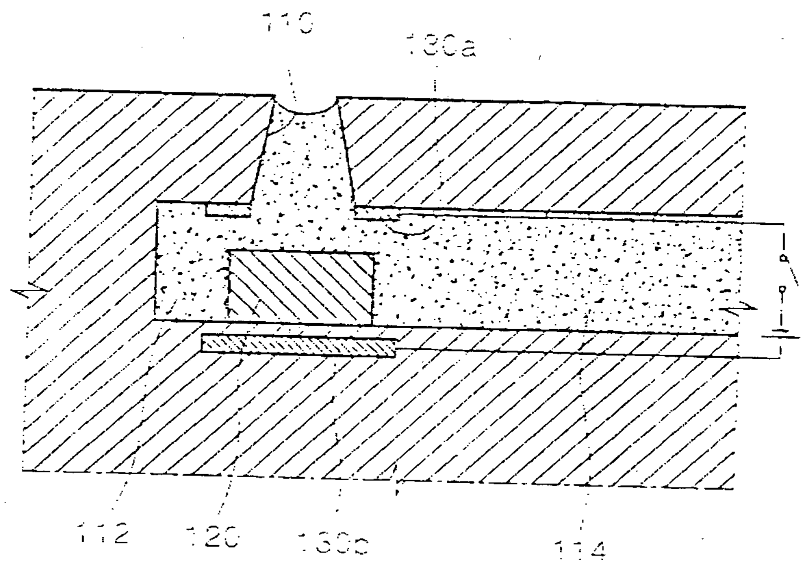


FIG. 8B

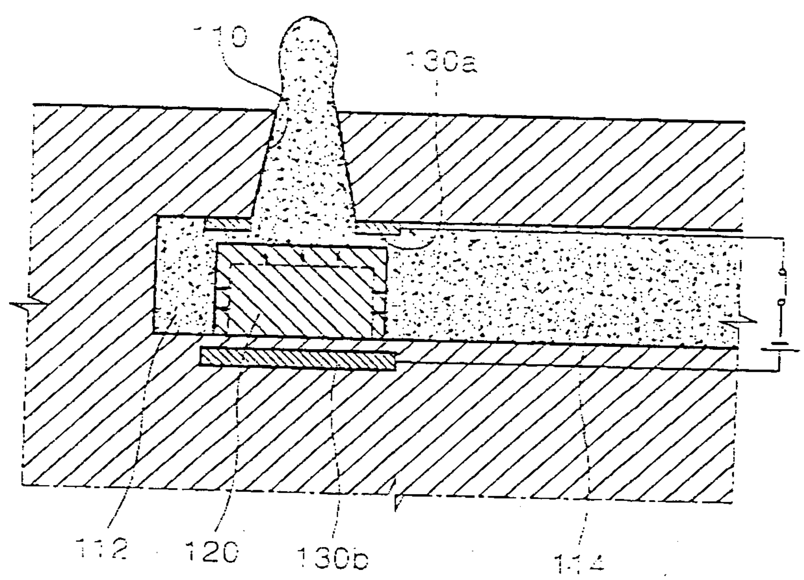


FIG. 8C

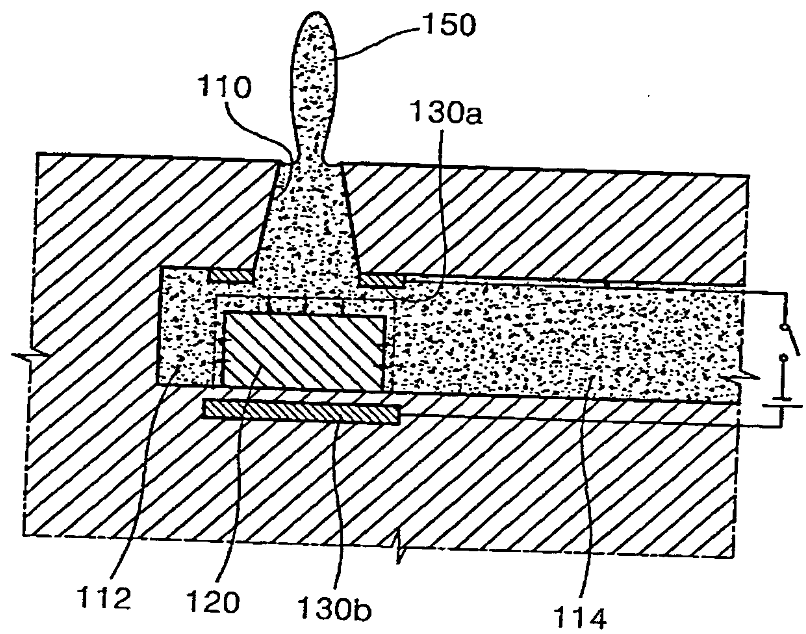


FIG. 8D

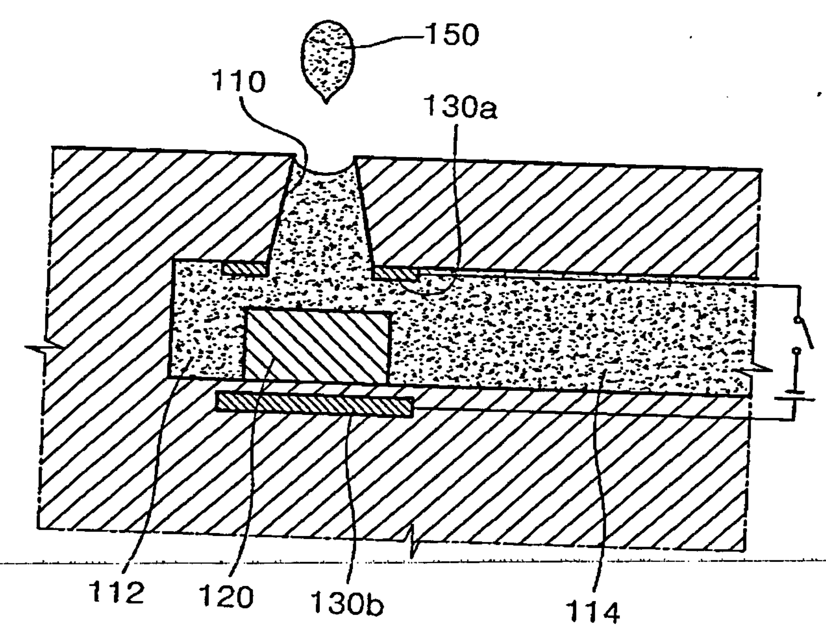
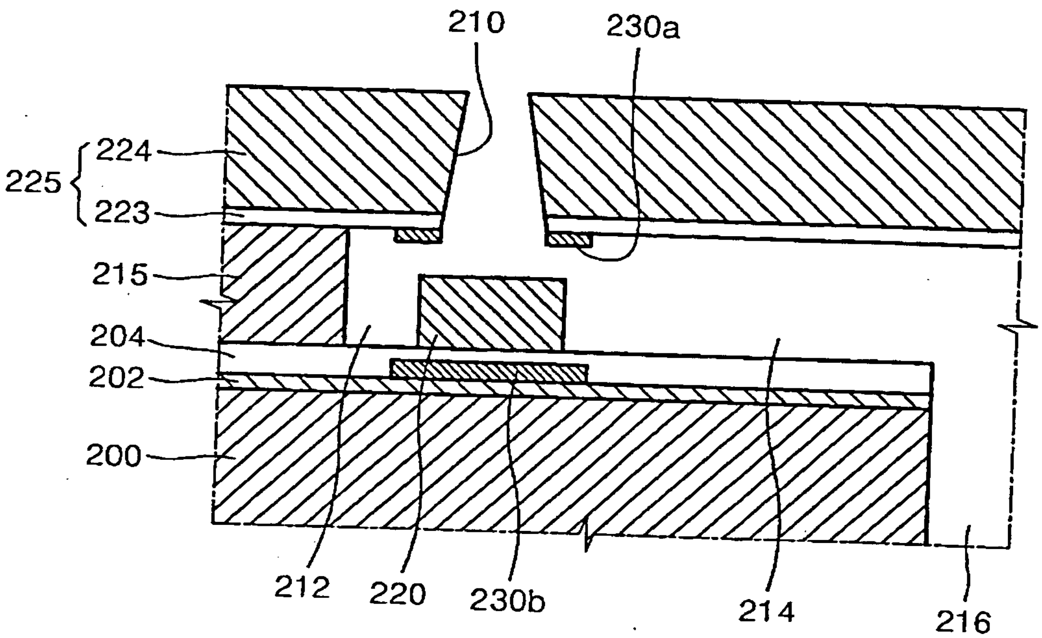


FIG. 9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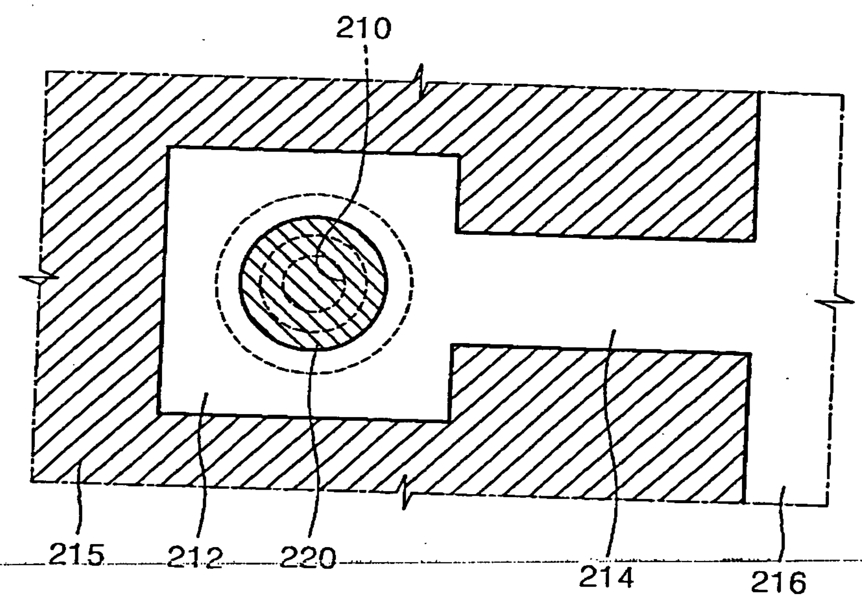
230a
225
224
223
215
204
202
200
212
220
230b
214
216

FIG. 10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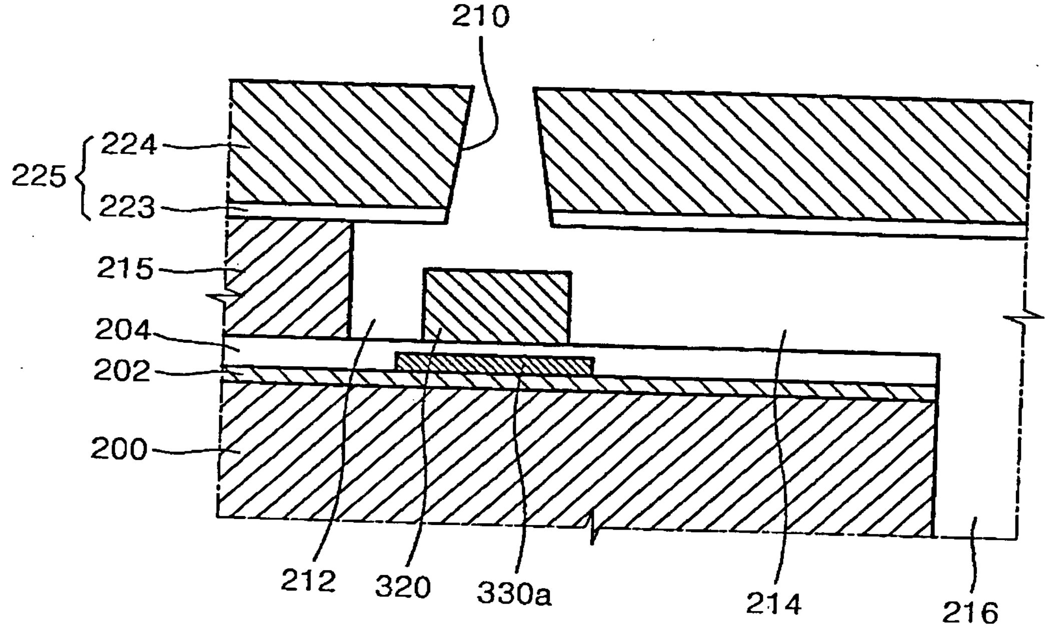
216

FIG. 11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224
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223
215
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202
200
212
320
330a
214
216

FIG. 12

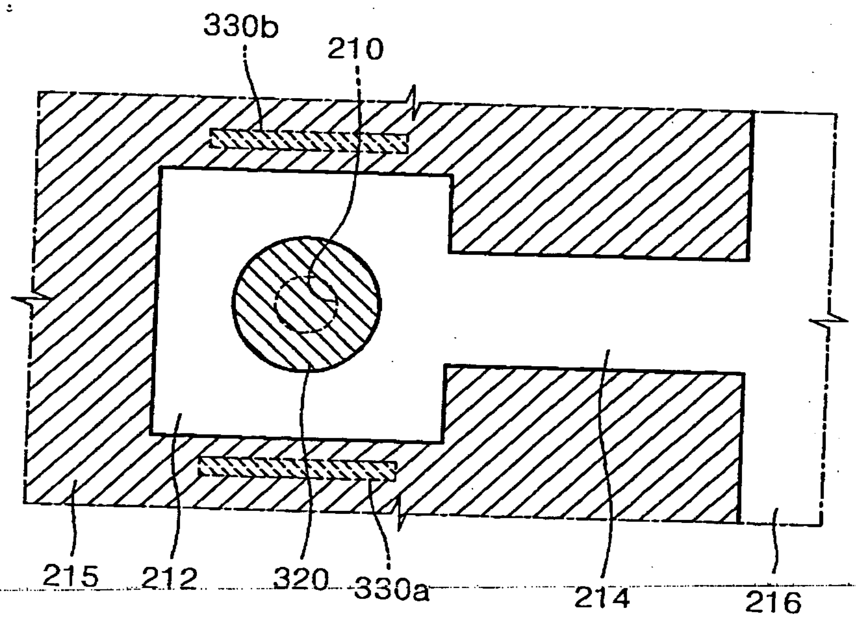
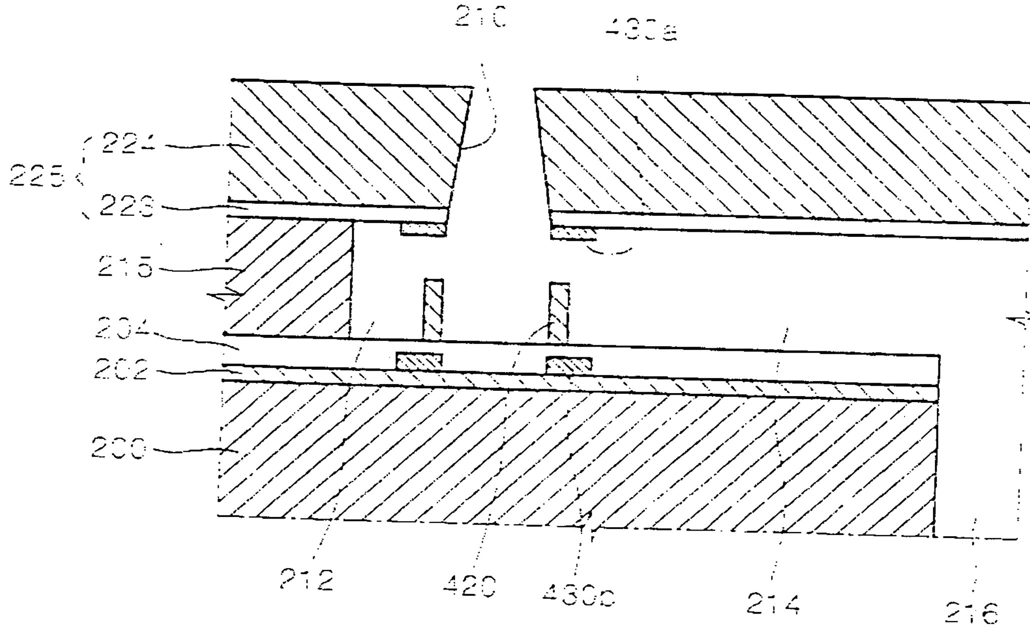

330b
210
215
212
320
330a
214
216

FIG. 13



210
430a
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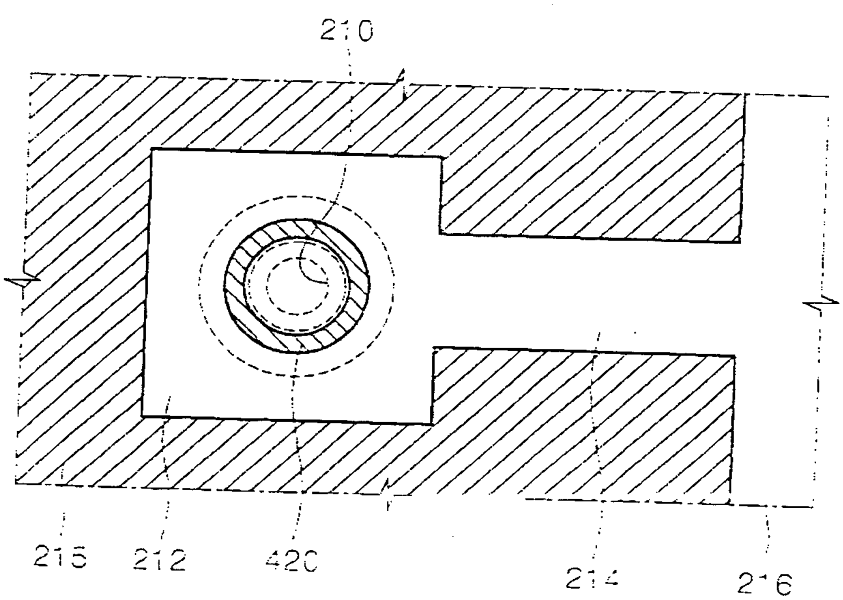
223
215
204
202
200
212
420
430b
214
216

FIG. 14



210
215
212
420
214
216

FIG. 15

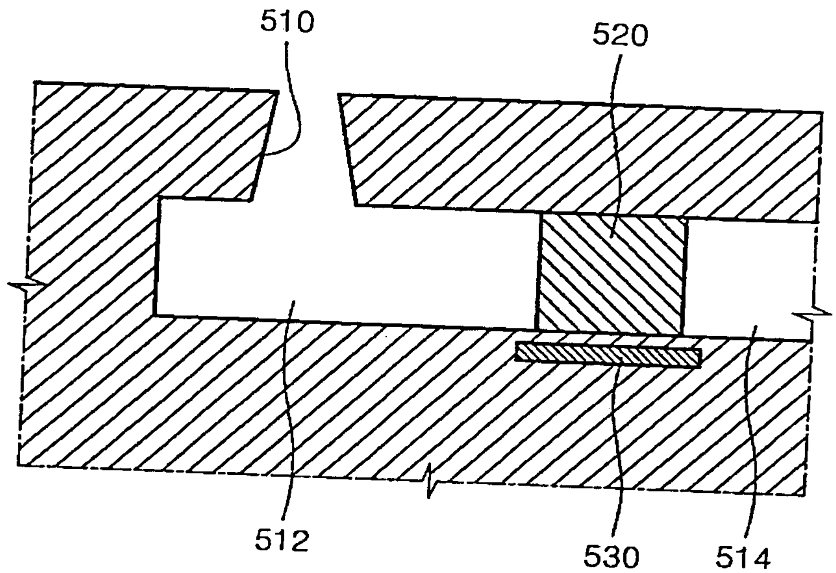


FIG. 16

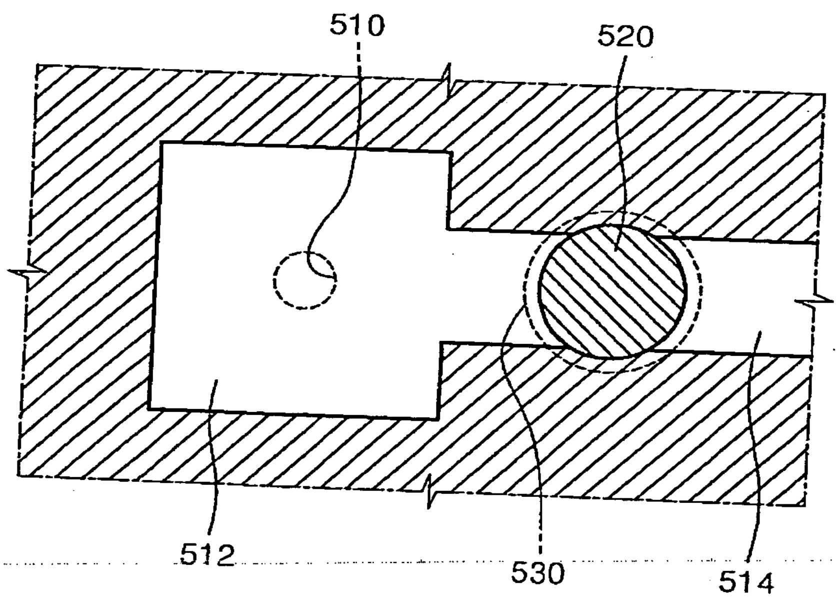


FIG. 17

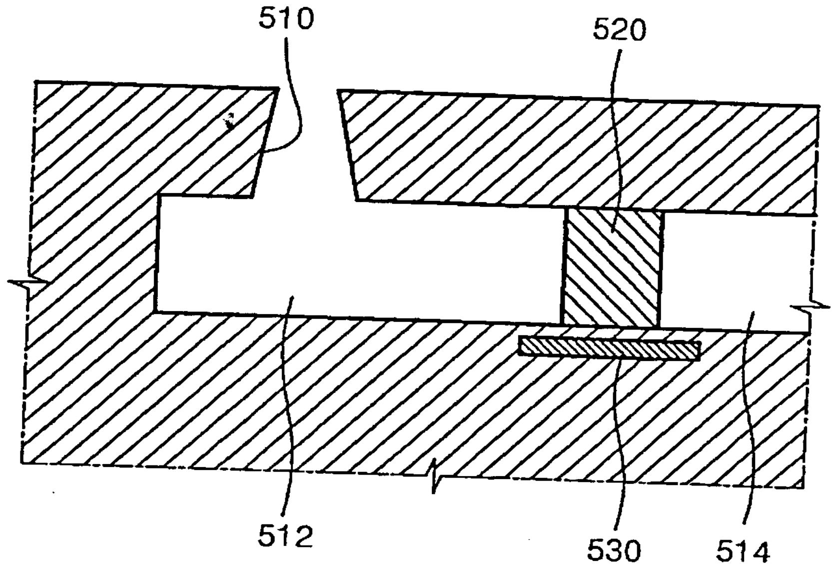


FIG. 18

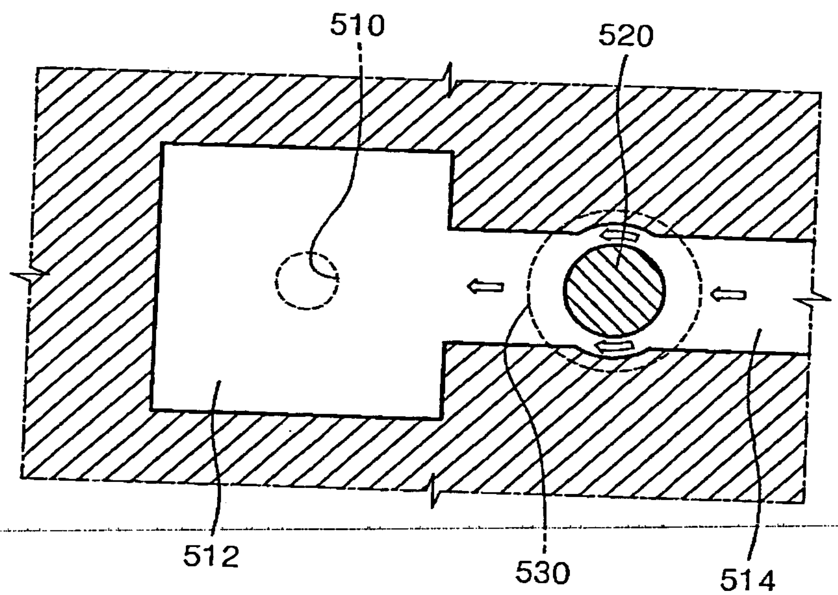


FIG. 19

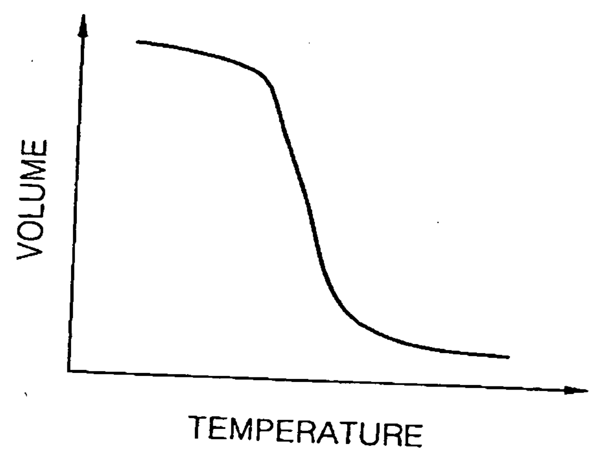


FIG. 20A

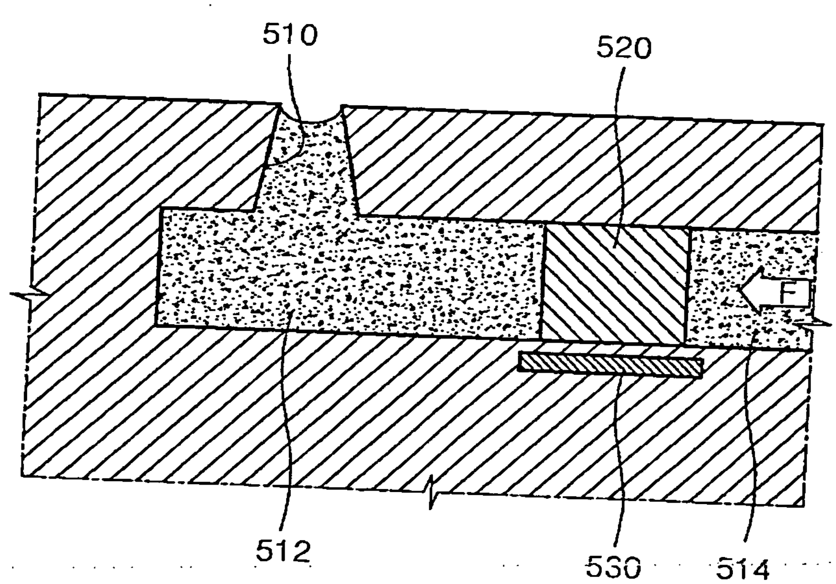


FIG. 20B

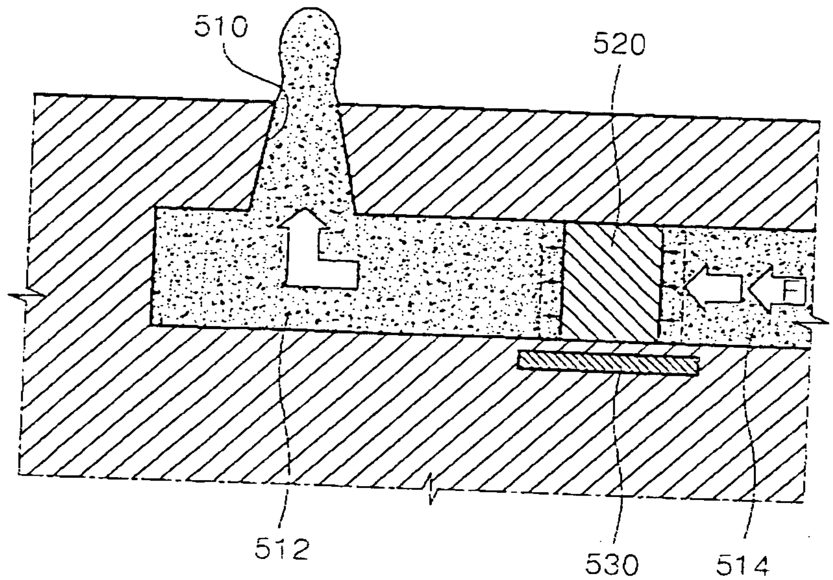


FIG. 20C

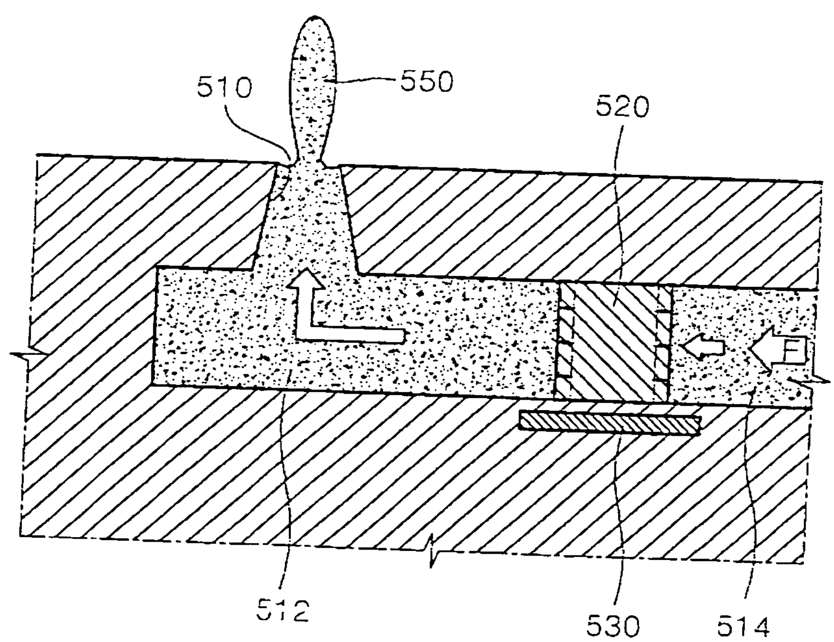


FIG. 20D

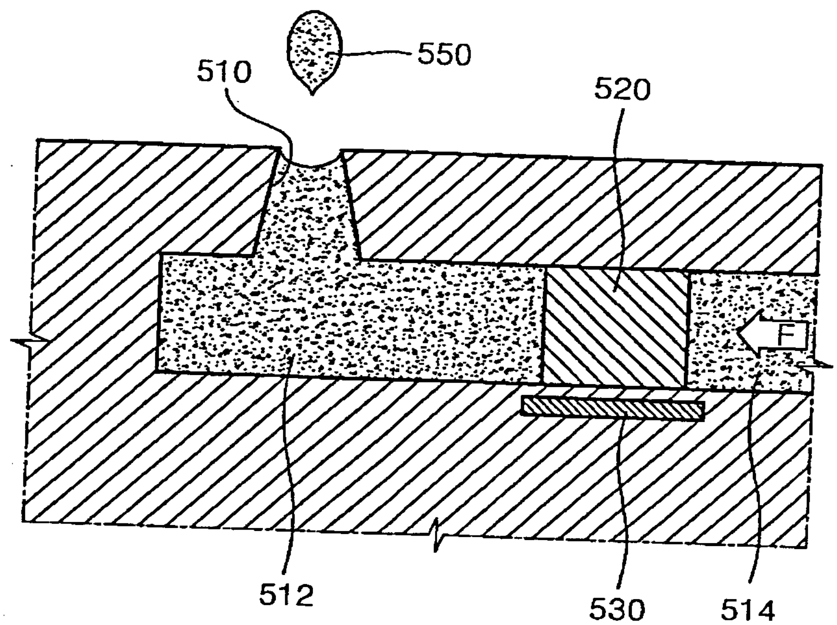


FIG. 21

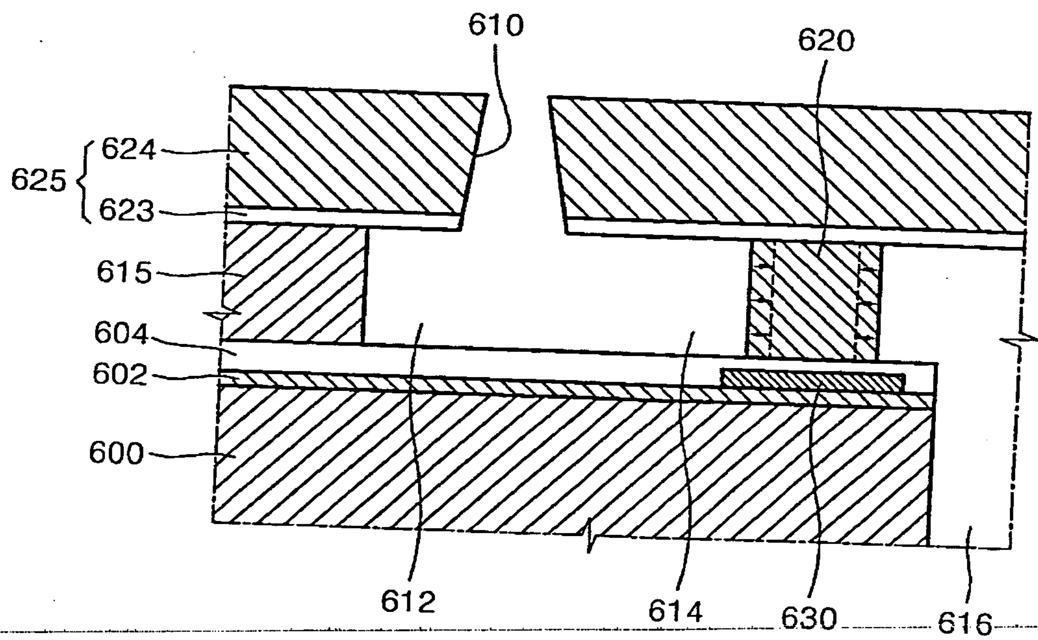


FIG. 22

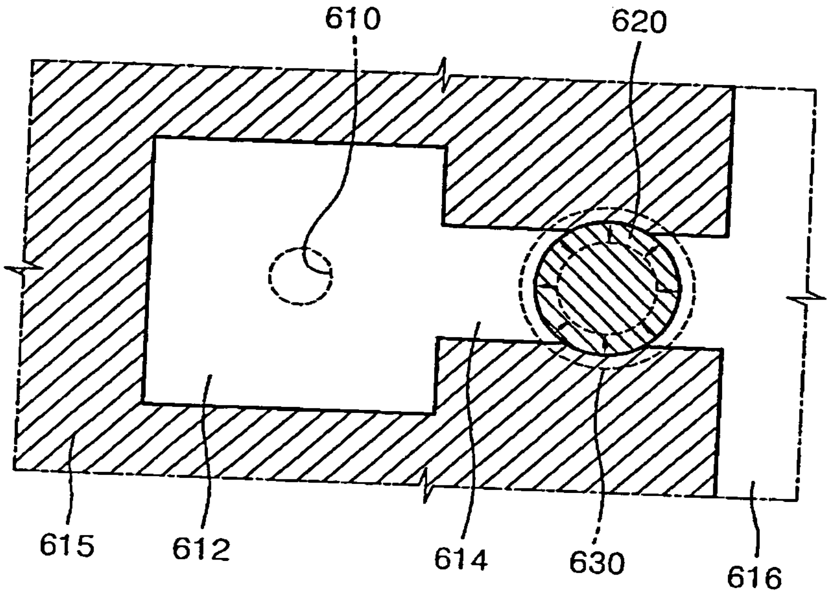

610
620
615
612
614
630
616

FIG. 23

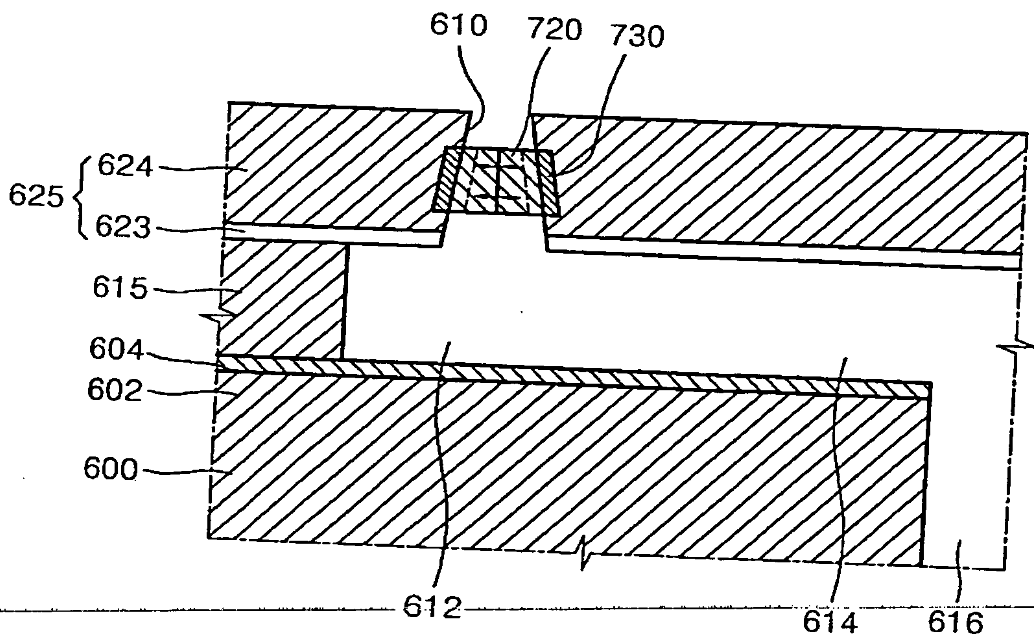

610
720
730
625
624
623
615
604
602
600
612
614
616

FIG. 24